Lectures on Geology.

PART III.

CHAPTER VII.

MATTER AND LIFE.

With the advent of life on the earth, a series of new phenomena made their appearance. Let us trace the differences between *Inorganic* and *organized* bodies, which characterize the two orders of phenomena.

In *Inorganic bodies* the forces of matter, attraction, cohesion, chemical affinities, electricity, magnetism, &c., are *alone acting*, and account for all phenomena. The laws of chemical affinities rule the *substance*. The laws of crystallization rule the *form*.

The most perfect, the normal, form of the mineral is the crystal. The surfaces of the crystal are planes, whose junction form angles of mathematical regularity.

Once formed, the crystal is a fixed body—no internal motion is observable. The mode of growth is by external addition of small crystals of the same form—all parts, therefore, are alike.

The crystal has no phases of growth differing from each other; the incipient crystal is just as complete as the larger one. There is no natural limit to its growth and size; no natural limit to its existence—no death. It stands as long as it is not destroyed by external influences. It has no power of reproducing, by internal process, a crystal of the same kind.

In *Organized bodies*, all forces of matter are acting, but they cannot account for all the phenomena; they are overruled and controlled by a new principle, a directing power which makes them subserve a higher end. That new directing power, essentially distinct from matter, is *Life*. Life is of its nature *immaterial;* for, when life is removed, no material element has been taken away; the dead body weighs exactly as it did when living; all atoms composing it are present, but, being now free,

they return to their natural allegiance; their chemical affinities take effect, and the organized body is decomposed.

In organized bodies, both plants and animals, there is a principle of individuality, a central power, a soul, and parts differing from each other, or organs performing special functions. All these organs, working together toward a common end and aim, for the benefit of the individual, under the guidance of the soul, constitute a living organism.

The fundamental organ of all organized beings, plants and animals, is the *cell*, a small bag, with thin, transparent walls, and full of a fluid, (*protoplasm.*)

The form of the cell, unlike the plane surface of the crystal, is more or less spherical, with curved surface. From the beginning it has in it *motion.* Inside of its walls, in the fluid it contains, small bodies are constantly moving around.

It has the power of reproduction, by an internal division, in two, four, or more parts, which become as many new cells; these, again, produce many more, gradually forming together a cellular tissue, and finally all the other organs.

The mode of growth of the plant and the animal is therefore by an internal process. Unlike the crystal, they grow from a seed, or an egg, and develop, passing through a succession of stages unlike each other, and closing the cycle of their life again by the production of a seed, or an egg, destined to give birth to another individual. Life is thus an uninterrupted motion, an unceasing evolution of individuals succeeding each other, gradually forming, and perpetuating a race.

Unlike the crystal, the plant and animal have a limit of size, of growth and lifetime, and a natural death.

In inorganic nature we find all the elementary bodies known to us, but only some 600 specific forms of minerals. In organic nature, oxygen, hydrogen, nitrogen, carbon, and some phosphor, make up almost alone the bulk of the body of all plants and animals, while 200,000 specific forms of plants, and nearly 500,000 of animals have been recognized. In the first, therefore, the *substance*—in the latter, the *form*—predominates.

The phenomena of organic nature are thus entirely distinct from those of inorganic nature; and this forces us to admit, as a

cause of these striking differences, the existence of a new element superadded to matter—*Life*—which has its own laws and modes of action.

The Life-System is a twofold one: the *Vegetable kingdom* and the *Animal kingdom.*

The plant expanding its many roots in the ground, and its branches and leaves in the atmosphere, takes up from both the raw materials, and under the influence of the sun's rays, transforms them into organic matter. It thus prepares food for the animal, and stores force which it does not expend. The animal takes it up ready-made, and expends it in action. The plant is thus the connecting link between matter and animal life.

Among the most important results of Geological researches are the following: It has been found that—

1st. The species of fossil plants and animals, though now extinct, belong all to one and the same organic system. Nay, they complete it, filling the gaps, and rendering the general plan more perfect and intelligible.

2d. These plants and animals make their appearance in succession, in an order corresponding to their rank in the scale of perfection of structure and functions, which constitutes a progress at every stage. In order to demonstrate these laws, we have to take cognizance of the classification of the innumerable varieties of plants and animals, which has been attempted, and to try to find out, if possible, the true rank and meaning of the great divisions established by botanists and zoölogists. We begin with the

Plant Kingdom.

The great divisions founded upon a similarity of structure, generally admitted as natural groups, are the following:

Two main divisions are founded upon the presence or absence of a flower:

The flowering plants, or *Phœnogams.*

The flowerless plants, or *Cryptogams.*

They are subdivided into four primary classes, founded upon the structure of the seed:

Dicotyledons, in which the germ is contained within two seed leaves, or cotyledons.

Monocotyledons, with one seed leaf.

Polycotyledons, with many, in indefinite numbers; also called *Gymnosperms,* because their seeds are naked.

The *Acotyledons,* without seed leaf: the seed being simply a cell, or *spore.*

They are summed up in the following table, with typical examples well known to every one:

	CLASSES.	TYPICAL EXAMPLES.
Flowering Plants, or Phœnogams.	Dicotyledons.	Oaks, Elms, Apple trees, Rose bushes.
	Monocotyledons.	Palm tree, Lily tribe, Grasses.
	Polycotyledons, or Gymnosperms.	Conifers (Pines, Cycas.)
Flowerless Plants, or Cryptogams.	Acotyledons.	*Vascular*—Acrogens, Ferns, &c. *Cellular* Mosses—*Thallogens* { Mushrooms, Lichens Algæ.

As the seed is but a plantlet of the same kind as the parent, it was natural to find in its structure and growth a repetition, in miniature, of the structure of the full-grown plant which produced it, and of its mode of growth.

In the *Dycotyledons,* in an almond, for instance, the germ or plantlet is between the two cotyledons, which are filled with food for the first need of the plantlet, before the roots and leaves are formed. The upper part, the *plumula,* already shows signs of two leaves; the lower, or root part, is separated from the upper by a collar. When germinating, it puts forth two germinating leaves, followed by others in pairs. The stem is branching in every direction; its additional growth takes place by the outside, (exogenous.) When a tree, it has a bark; the leaves show a branching venation, often quite complicated; the flower is complete, with calyx and corolla, protecting the stamens and pistils; the seed is provided with several envelopes.

In *Monocotyledons* the germ is surrounded by a single seed

leaf; it puts forth a single germinating leaf, followed alternately by others. The stem is not branching; its growth is inwardly, (endogenous,) and at the top; the leaves show a parallel nervation, very rarely branching. The flower has no calyx; the seed only one envelope.

Gymnosperms have branching stems, and are exogenous, like the Dicotyledons, but their leaves are slender, but little developed; the flower is reduced to stamens and pistils without corolla; the seed is naked.

In *Acotyledons* the seed is a simple cell, with germinating power, a *spore;* the growth is by a multiplication and reproduction of cells.

In the *Vascular* cryptogams the cells develop into a system of vessels and beautiful leaves, as in ferns; and of stems, as in tree ferns, always growing at the top; hence the name of *Acrogens.*

In *mosses,* the forms of leaves and stems are preserved, but the whole fabric is but cellular tissue.

In *Thallogens,* the difference between leaves and stem is obliterated. They are but a mass of cellular tissue expanding into different directions.

The question which interests most the geological succession of plants is that of the *rank* in the scale of perfection which belongs to each of these classes. From the thallogens to the dicotyledons there is an increasing complexity of structure which has been regarded as the criterion of a lesser or greater perfection of the plant. This view, though true in a measure, does not exhaust, as we believe, the signification of these great divisions. We must go deeper. We must pay attention to the organs as instruments for *life functions,* and to their combination.

In each class below the dicotyledon, we observe that one particular organ of the plant shows a greater degree of perfection, a prominence over the others, and thus becomes characteristic of the class, while others remain in a condition of relative inferiority. In the dicotyledons, however, all are harmonized and most perfect.

In the Cellular Cryptogams the *cellular tissue* is alone present, and is, therefore, the prominent organ; cell life the prominent function.

In the Vascular Cryptogams, or Acrogens, the *leaf,* as in ferns,

rivals in beauty and perfection that of dicotyledons. Indeed the whole plant is but a leaf, or a bunch of magnificent leaves.

In Gymnosperms, the *stem* is the most perfect part. It is branching, has a regular bark, is exogenous, as in dicotyledons, while the flower and leaf are of the lowest kind. The whole tribe is arborescent, with woody stems.

In Monocotyledons, the brilliant *flowers* of the lily tribe, of the aloes, hyacinths, tulips, palm tree, *coco nut seeds,* approach perfection, while the leaf is inferior to that of the fern, and the stem lower than that of the gymnosperms.

In Dicotyledons, however, all the organs show the highest degree of perfection. All the scattered excellencies of the lower types are here united. The highly elaborate structure, internal and external, the increased variety of forms, prove them to be the highest expression of vegetable life, the synthetic, *perfect type* of the plant, towards which the other are but steps of *partial progress.*

Moreover, a similar predominance of one of these fundamental organs characterizes every successive life-phase of the growing plant, indicating the true rank of each class in the system of plant-life.

The formation of the *cellular tissue* prevails during the period of germination; next comes the development of the *leaves;* the growth of the *stem,* or a *trunk,* follows, when necessary to bear a more abundant foliage. The reproduction phase begins with the *flower* and is consummated by the *seed.*

These various relations are clearly shown in the following table.

RANK.	CLASSES.	PREDOMINANT ORGAN.	PHASE OF LIFE.
Synthetic or Harmonic type.	Dicotyledons.	Normal subordination.	The perfect plant.
Types of partial progress.	Monocotyledons.	Flower and Seed.	Flowering and Seeding.
	Gymnosperms.	Stem.	Stemming,
	Acrogens.	Leaf.	Leafing.
Embryonic type.	Cellular Cryptogams.	Cellular tissue.	Germinating.

In the infinite variety of the vegetable kingdom we thus behold an admirable plan, unfolding the totality of plant-life in its unity, and exhibiting in stereotyped forms the great phases of its development. We shall soon see how this plan tallies with the succession observed in the Geological Strata.

Animal Kingdom.

Distinction between plant and animal. As said above, the main function of the plant is to transform inorganic into organic matter, composed of unstable chemical compounds, and thus prepare food and force for the animal. It stores that force, and does not spend it. The animal is made for *action.* It takes by food that ready-made force which it cannot make, and spends it in action.

The life of the animal being activity, it is endowed with *sensation,* by which it becomes conscious of the impressions received from the external world, and with a *will* to react upon it. *Sensation and will,* and as a consequence, *voluntary motion,* are characteristic of the animal.

Plants and animals thus differ in their functions in the economy of nature, and in their organization which is fitted for these functions.

Classification. At the beginning of this century *Cuvier,* the founder of Comparative Anatomy, showed the fact that notwithstanding the immense variety of animals, there are but four great plans of structure, or four *archetypes,* under which all animals can be classified. These archetypes are the following:

Plans of Structure, or Archetypes.

1. *Radiates.* All their organs are arranged around a centre, radiating in five or more directions. We do not yet see here the *animal structure,* in which all the organs are grouped around a *medial line,* with *head* and *tail* on the opposite ends. They are like plants, inasmuch as their parts are radiately arranged about a central axis, and are often attached to the ground, which is the plan of structure common to all plants. Yet they are strictly animals, as they have a mouth and stomach and other animla

organs, and the power of voluntary motion. The star-fish, jelly-fishes and polyps, are examples.

2. *Mollusks.* These have soft, fleshy bodies, with the organs on both sides of a *medial line*, and not radiating as in the former class. The whole body is a soft mass of muscle, which is generally protected on the outside by a shell, as in the snail, or a leathery skin, as in the cuttle-fish. Oysters, clams, snails, and cuttle-fishes belong to this class. The oyster has no head; the snail has one. They are entirely unlike radiates, and characterized by a complete absence of articulations.

3. *Articulates* are composed of a succession of rings fastened together, each ring having a separate life of its own, possessing a nervous system; each having also its own holes for respiration, and often a pair of legs. Hence, if we cut a wasp in two, each part will live quite a while, and respiration will still continue, though the animal has lost half its body. The great difference between articulates and mollusks is, that while in the latter there is a complete absence of articulations, or joints, in the former, as the name indicates, they are the leading characteristic. Of this class, insects, spiders, craw-fishes, worms, &c., are examples.

4. *Vertebrates.* These are entirely different from the preceding types. They have an internal, bony structure, called a skeleton, which supports the soft parts outside. The most prominent feature of the skeleton is the vertebral column, or back-bone, and spine to which ribs are attached, making a grand cavity for the respiratory and digestive organs. This *vertebral column* is made up of a number of joints, each of which is called a vertebra. Along this column there is a series of processes forming a "bone-sheathed cavity" for the great nervous cord, or the *cerebro-spinal system*, which, when it reaches the top of the column, expands into the brain. This is the highest class, and is the one to which man belongs.

A preface to the system of life is formed by *protozoans, rhizopods* and *infusoria*, &c. These animals have no internal structure; only a cell or mass of cells. No nervous system has been discovered, but must be present, as there is sensation. For protozoans, see Dana, p. 271. Rhizopods are little animals which are

merely elongated cells. The only apparent organization is the shell outside.

The following table gives the classification of Cuvier, slightly modified by Agassiz:

ANIMAL KINGDOM.

Plans of Structure, or Archetypes.

Radiates.	*Mollusks.*	*Articulates.*	*Vertebrates.*
CLASSES	CLASSES.	CLASSES.	MAMMALS.
Echinoderms.	Cephalopods.	Insects.	Birds.
Acalephs. (Jelly-fishes.)	Gasteropods.	Crustaceans.	Reptiles.
Polyps.	Acephals.	Worms.	Fishes.

No special structure—Protozoans, Sponges, Rhizopods, Foraminifers, &c.

Now, what is the meaning of these great types of structure; why are there four, and no more or no less; and what is their rank in the scale of perfection of animal life? To answer these questions, we must remember that the structure is but the expression of the life-functions for which the organs are made; and a closer examination will convince us that each archetype has a predominant life-function which determines its special form and the character of its physiological life. It will be seen, also, that each archetype corresponds to one of the fundamental functions of life.

These fundamental physiological functions are the following:

Fundamental Physiological Functions of the Animal.

1. *Cell Life.* *The development of the cell* makes up the animal. Every part of the body is an accumulation of cells, which are developed by the growth of the cellular tissue, and shaped into

the different organs. This, therefore, is the most fundamental life-function.

2. *Nutrition—The Nutritive System.* In the higher animals this is essentially the digestive organs: the stomach, which melts the food; the intestine, which absorbs it; the chyle, which brings the prepared food into the blood, which is forced through the body by the heart, reaching the cells by which it is assimilated; whence life and growth are maintained. All this is the nutritive system, composed mainly of the *digestive* and *circulatory*, or *trophic*, systems.

3. *Respiration.* This is necessary to all animal life, and produces, by combustion, animal heat and force, and is closely connected with motion. No animal can live without some kind of respiration. There are different organs for this. Most animals respire by lungs; insects, by the whole body; polyps and worms, by the skin. Fish breathe by gills, while frogs have gills first and lungs afterwards.

4. *Sensation and Will.* The former acts on the soul, the latter from the soul on the body. This function is the chief characteristic of the animal. Its organ is the *nervous system.* There are two sets of nerves—afferent and efferent. The former are nerves of *sensation,* by which impressions from without reach the brain. The latter are nerves of *motion,* by which a communication is sent, as by telegraphic wires, from the brain to the muscle, thus causing it to move. A muscle has no power of its own to move. When the nerve is diseased, man cannot act. The well-known disease of paralysis is simply loss of nerve-action. Nerves transmit the orders of the will. This is the highest animal function—the faculty of sensation and will.

These four functions are all necessary to animal life. The fifth, reproduction, though necessary to the life of the *species,* is not to that of the *individual.*

Let us now see which of these life-functions predominates in each of the archetypes, and becomes its characteristic distinction.

Radiates are subdivided into three classes—Polyps, Jellyfishes, and Echinoderms. The polyps are but a digestive skin. Their reproduction by division, and by budding like the plant,

which secured for them the name of zoophytes, are evidences of the predominance of the cell life over all the other functions. The plan of structure itself is but that of the whole plant kingdom, in which all the organs radiate from a centre.

Mollusks are subdivided into Acephals, Gasteropods, and Cephalopods. Here the predominance of the nutritive function is evidenced by the vast amount of muscle developed at the expense of motion, and the rapidity of growth, and the full development of the circulatory system. Hence the absence of articulation in the whole body. A snail is an emblem of sluggishness.

In *Articulates* the respiration takes place through the whole body. It is so active in insects—bees, for instance—as to produce a vast amount of heat, and give them that power, that activity and endurance of motion which astonishes us in these little bodies. The articulated structure is made for easy and rapid motion.

These three physiological functions—cell life, nutrition, and respiration—all belong to the growth of the body, which takes place without the direct intervention of the will of the animal.

In *Vertebrates*, however, the life and sensation and will overshadow all the other functions. The three main physiological functions which are foremost in the Invertebrates occupy here only a second rank. The involuntary life makes the body; the voluntary life uses it. The life of sensation and will, being the highest and ruling characteristic of the animal, we say that the vertebrate is the true, *typical*, most perfect animal. It combines all the excellencies of the lower types, which in it are subordinated, as it should be, to the higher voluntary life.

This view of the Animal Kingdom enables us to understand the meaning of the great archetypes, and gives a reason for their number of four, corresponding to the four fundamental life-functions. It teaches us also the relative rank and value of each in the system of life, as well as of all the classes in each archetype.

Accordingly we distinguish two primary divisions or *Sub-Kingdoms*—the first containing the *Vertebrates* as representatives

of the Voluntary life and Intelligence; the second, the three Invertebrate archetypes, representing the system of Involuntary life and Instinct.

The following table gives a clear synopsis of the classification just explained.

Animal Kingdom.

A.—*Sub-Kingdom of voluntary Life and Intelligence.*

RANK.	ARCHETYPE.	PREDOMINANT PHYSIOLOGICAL ORGAN.	GRADE.
Synthetic, or Harmonic type.	Vertebrates.	Nervous System.	Typical, perfect Animal.

B.—*Sub-Kingdom of Involuntary Life and Instinct.*

Invertebrates.

Types of partial progress.	Articulates. Mollusks.	Respiratory. Digestive. Circulatory.	Motorial Nutritive.
Embryonic Type.	Radiates.	Cellular Tissue.	Vegetative.

The same feature is found in the classes of the Invertebrates. The Polyps, Acephals and Worms are *Vegetative* types; Acalephs, Gasteropods and Crustaceans are *Nutritive* types; Echinoderms, Cephalopods and Insects are *Motorial* types, of their respective Archetypes, gradually rising to their full typical forms.

The vertebrates themselves, being the true animals, repeat in their subdivisions a similar arrangement, as seen in the following table.

VERTEBRATES.

RANK.	CLASS.	PHYSIOLOGICAL SYSTEM PREDOMINANT.	GRADE.
Synthetic or Harmonic type.	Mammals.	Normal subordination to nervous system.	The typical, perfect animal.
Types of partial progress.	Birds.	Respiratory,	Motorial.
	Reptiles.	Digestive, Circulatory.	Nutritive.
Embryonic type.	Fishes.	Cellular and Muscular tissue.	Vegetative.

The mammals again, though being the typical Vertebrates, and thus representatives of the higher life of intelligent will, still show, in each of their great divisions, a greater or less influence of the physiological functions of the lower life, which becomes characteristic of these great groups. The vegetative life still prevails in the bulky water-types, the *Cetaceans*, and in the sluggish land *Edentates.* The nutritive function shows its influence in the *Herbivorous* mammals, among which are found the largest land animals, and upon which man mainly depends for food. In the *Carnivorous,* the activity, the relatively greater strength and wonderful agility, which enable them to overcome their prey, are strong indications of the motorial grade—while in the monkey the prevailing animal intelligence already prefigures, though still in animal form, the coming creation of *Man,* who is the typical, perfect mammal, the *absolute Synthetic form of the whole animal kingdom.*

Here, as in the plant kingdom, an intelligent plan is evident by which all the great functions of animal life are represented, diversified by their different combinations, but bound into a unity which is life itself.

Man is thus the key of the vault of the system of life; but he

is also something more. A new internal sense, the sense of the invisible, of the infinite, which does not exist, even in germ, in the highest animal, places him in an entirely new sphere of existence. This spiritual eye enables him to discern the exisistence of an invisible world, to believe in, fear, love and adore his invisible Creator, and makes him fit to become a living member of the great community of spiritual beings.

By his body Man belongs to and is the head of Nature's life; by his soul he is a part of the spiritual world. Man is thus the link between Nature, in its totality, and the Spiritual world, as the plant is the link between Matter and Life.

CHAPTER VIII.

THE GREAT AGES OF LIFE.

Introductory Remarks.—We have examined the system of life of animals and plants, and have now to see how far the order of succession in geological times corresponds to this system of life. These organic forms have been called into existence, one after another, according to a law. To find out that law is now to be our study. The order of strata is the only indication which we have of the regular succession of geological events. These strata and their fossils must be examined in order, beginning with the lowermost. Nearly all geological names are local names. But when a corresponding series of rocks, made, as far as we know, at the same time, are found in other localities, the same geological name is given. It is difficult to *parallelize* the strata of Europe, America, and different continents, but it has been done by means of their relative position and the similarity of fossils—both plants and animals. Thus ages of life are recognized which extend to all continents. Each age covers *all the surface* of the globe, and hence is not a local phenomenon.

Each age comprises a series of rocks, with many subdivisions or formations, containing the fossil remains of plants and animals living during their deposition. These rocks are usually unconformable with the preceding and following ones, indicating changes in the physical geography of the lands and seas.

Each new age is marked by the advent of new forms of plants and animals, the extinction of all, or most, of the previous ones, and by the predominance of a special class, which gives it its character as an age of life.

I.—Archæan, or Eozoic Age.

Below the fossiliferous rocks are found, in Canada, two series of rock strata of immense thickness—the lower, or Laurentian, series (from the St. Lawrence river), 30,000 feet thick, and the Huronian series (from Lake Huron), some 10,000 to 20,000 feet thick. These rocks, being the oldest known to geology, have received from Dana the name *Archæan* rocks. They are largely metamorphic, granite, gneiss, schists, with intercalated layers of limestone, which passes into marble; all are much contorted and disturbed.

The Archæan rocks in North America are spread, in the form of a V, from the great lakes to Labrador on the northeast, and to the Arctic ocean on the northwest, already indicating the two main directions of the future mountain chains—Appalachian and Rocky Mountains — which control the form of the continent. They are the primitive kernel of the continent of North America. The lines of Archæan rocks, in the Highlands of New Jersey and in the Rocky Mountains, mark the place of these incipient mountain chains.

No fossil plants, nor animals belonging to the four archetypes, are found in them, but an abundance of graphite (carbon) seems to indicate the existence of some kind of infusorial plant life, and the presence of limestone that of low animal life. Indeed, Prof. Dawson, in Canada, believes to have recognized in the Laurentian, and in great abundance, a gigantic coral-making rhizopod, which he calls *Eozoon Canadense*. Though not absolutely proved, the existence of these lowest forms of plant and animal life is highly probable. This would be a beginning of life, such as might have been expected, by protophytes and protozoans—a preface to the more definite life system; and the Archæan Age may then well be called the *Eozoic Age*, the dawn of life.

Palæozoic Time.

The Palæozoic time, or the time of the *oldest animals*, as the name indicates, forms, as it were, the first volume of the history

of life, of which the Eozoic Age is but the preface. In its rocky leaves, in the Palæozoic series of strata—which, in the Appalachian region, are accumulated to the thickness of nearly 40,000 feet—appear, for the first time, the distinct forms of life which belong to the great archetypes above delineated. So abundant and varied was life during this long interval of the earth's history, that over 20,000 species of fossil remains have already been described, and new ones are found every day.

The Palæozoic system of rocks contains three *ages*, which may be called the three great beginnings of the life-system:

The *Silurian Age*, or age of the *Invertebrates;* the beginning of the lower, involuntary life-system.

The *Devonian Age*, or age of *Fishes;* the beginning of the higher, voluntary life-system.

In both these, life is exclusively *marine.*

The *Carboniferous Age*, or age of *Aerogens;* marks the beginning of land-life by an exuberant vegetation, mainly composed of cryptogramous land-plants.

II.—Silurian Age, or Age of Invertebrates.

Above the Archæan rocks, and uncomformable with them, are spread a large series of rocks called *Silurian.* The name has been given by Sir Roderick Murchison to rocks of the same age in Wales, England, from the *Silures*, its ancient inhabitants. The Silurian rocks are richly developed in North America, especially in the northern parts. They are composed of strata of sandstones, conglomerates, limestone, shales, and slates, the nature of the rocks often changing abruptly in the successive beds.

What we have learned of the mode of formation of these rocks may give us a clue as to the causes of these changes. We have seen that sandstones and conglomerates, which require considerable water-power for the transportation of their materials, are shallow-water or shore formations. Compact limestones, due to Foraminifers and other Rhizopods, are formed in deep, quiet waters. Coralline limestones, again, belong to shallow waters. Slate deposits require the absence of the motion of surface waves.

We have, therefore, to admit alternate rises and subsidences of waters.

When the land is brought near the surface, sandstones and conglomerates are deposited; when it sinks, limestones are formed. These differences in depth will also account, in part, for the changes in the animal life and the relative greater abundance of fossils. Sandstones and conglomerates mean turmoil and destruction, rapid accumulation and scarcity of life. Limestone means quiet waters with development of life, slow deposition, and therefore abundance of fossils, generally in a better state of preservation. The limestones usually occupy the middle of the series of rocks constituting an age, which begins and ends by destruction and fragmental rocks, and they contain most of the fossils characteristic of the age.

The Silurian Age is divided into the *Lower* Silurian and the *Upper* Silurian—two series in which life differs considerably. Each is subdivided into *periods*, differing again by their characteristic fossils. As all these rocks are well displayed in the State of New York, and their succession and fossils have been carefully studied, the names of the subdivisions established among them have been generally adopted as standards for American geology.

A.—In the Lower Silurian these periods are:

1. The *Primordial*, with the Potsdam sandstone.

2. The *Canadian*, with the Calciferous sandrock and Chazy limestone, in New York.

3. The *Trenton* Period, with the Trenton and Cincinnati limestone and Utica shales.

B.—In the Upper Silurian:

1. The *Niagara* Period, with the Medina sandstone and Niagara limestone.

2. The *Salina* Period, with the Onondaga salt-group.

3. The *Lower Helderberg* Period, with numerous limestones.

4. The *Oriskany* Period, with the Oriskany sandstone.

Silurian Life.

Primordial Period.

Some remarkable facts are connected with the first introduction of life.

1. *Plants* are all marine, seaweeds, so-called Fucoids.

2. Among *animals* the three archetypes of the Invertebrates make their appearance *suddenly;* no transitory forms from the Protozoans to higher, intermediate, forms being found.

3. The three archetypes do not succeed each other, as might have been expected, in the order of their rank of organization, viz., Radiates first, Mollusks next, Articulates last; but they all appear *together.* This important fact was first brought to light by Agassiz.

4. In the lowermost fossiliferous strata, the Radiates are only represented by a few *Crinoids,* of the class of Echinoderms, and by *Graptolites,* possibly coral-making Acalephs. The Mollusks have representatives of all their classes—*Brachiopods, Gasteropods and Cephalopods.* Among Articulates a few *worms* and an abundance of Crustaceans, *Trilobites,* indicate the presence of the two lower classes. Thus not only all the archetypes of the Invertebrates, but all their classes are found except the lowest, the polyps which appear a little later in the Silurian, and the highest, the insects, which belong to another age.

5. The earliest types are not the lowest of their class. The Crinoids belong to the highest class of the Radiates; the Cephalopods to the highest of the Mollusks; the Brachiopods, so abundant and characteristic of the Palæozoic time, are by no means in the lowest rank of the class; the Trilobites though an embryonic form, belong to the middle class of the Articulates, the Crustaceans, in which they are by no means the lowest form. The Polyps and Bryozoans, the lowest of the Radiates and Mollusks, are absent from the Primordial Zone of strata, and the worms are but poorly represented.

These striking facts seem to force us to the conclusion that, in the present condition of our knowledge, the idea of a genetic

evolution of all these animal types from some protozoan life, or from one another, is inadmissible.

But the creative idea which seems to be revealed by the results of these careful geological investigations, is that of the simultaneous ushering into existence of a complete system of the *lower* or *involuntary* life, as we have called it, represented in its great outlines by the world of Invertebrates which filled the waters with life, and reigned supreme and alone during the long age of the Silurian.

Perhaps it is on account of this feature of the time that the Molluskan type, the middle one, and the most characteristic of Invertebrate life, is also the most perfectly developed. Not only are all its classes fully represented in number and variety of species, but it offers in its gigantic Cephalopods, (Orthocezas, &c.,) whose straight shell was nearly a score of feet in length, at once a perfection of internal organization which approaches that of the fish, and a bulk and power which makes these monstrous Mollusks the kings of that first creation.

The following periods of the lower and the upper Silurian only expand and perfect that system of life. In the Trenton period, the number of species already exceeds 2000. Later it still increases to over 10,000. More elaborate and ornamented forms succeed simpler structures. Species and genera are destroyed or gradually die out. These changes are especially notable from the lower to the upper Silurian.

A last feature reveals us another law: In the uppermost strata of the Silurian, a few species of fishes of small size are found, heralding the coming of the Age of Fishes. This fact, as it will appear later, is not an isolated one. Before each new age some forerunners of the coming group of animals are found: a few small, amphibious, reptiles in the Carboniferous Age; a few marsupial mammals in the Mezozoic, announcing the coming Age of Mammals.

III.—The Devonian Age.

The period of Devonian Rocks—so called because this formation is very distinctly traced, and of great extent in Devonshire,

England—is specially represented by red sandstone, and hence has been appropriately called the "Old Red Sandstone Age."

Vast shallow seas, covered with a few islets, form the ideal of this period.

It commences with a series of fragmental conglomerate, indicating a time of turmoil; this is followed by strata of limestone, denoting a time of quiet and deep seas, and, finally, the age closes by a series of fragmental rocks denoting the breaking up of the older rocks and destruction of the existing species of life.

The periods distinguished in the New York rocks are:

1. The Corniferous Period, or Lower Devonian.
2. The Hamilton Period,
3. The Chemung Period, } or Upper Devonian.
4. The Catskill Period,

Growth of the Land in this Age.

While the rocks in the west of this continent were of limestone, those in the east were of sandstone. Now this sandstone indicates shallow water, as well as a process of disintegration. This shows that the Appalachian border was already rising under the water. If the theory is correct, that the relief of the globe was caused by the wrinkling of the harder crust on account of the contraction of the inner portions, it is evident that this process must, in some cases, have been very gradual. We have, then, the border growing first, while the interior was still under water. We remember that in such a condition of shallow water the growth of coral is produced; therefore around the whole region of the Mississippi plain there were at this time immense coral reefs.

Life in the Devonian Age.

Plants. As we have seen, the plants of the Silurian age were, with rare exceptions, altogether marine, and these in no great abundance. Now, however, land plants made their appearance; very different, however, from those of the present day. Crypto-

gams, of which the ferns and club-mosses convey some idea, would form the chief part of this primitive land vegetation.

Here, as in the case of the first animals, there are no signs of transitory forms, from the leafless, stemless sea-weeds to the stately tree-ferns, lepidodendra, and pines. The land plants begin at once with comparatively high types.

Animals. In the Invertebrates we note an extraordinary development of corals and coral reefs. The first winged *insects* make their appearance, and complete the system of the Invertebrates. But the greatest event is the birth of the higher system of life, by the introduction of the archetype of the *Vertebrates*, in its aquatic form—the fish.

The class of fishes seems to have held the first rank of importance in the Devonian fauna. Its first representatives—the Selachians (sharks), Ganoids, and Placoderms, all of the order of cartilaginous fishes—are of no inferior grade, but are at once possessed of a high organization, and are large, powerful and voracious animals. Some, like the Dinichthys, of Ohio, may have reached twenty feet in length. They combine both fish and reptilian characters, being—as most of the early types—such as Dana calls "comprehensive," because they comprehend peculiarities of various types. The Ganoids are protected by a covering of hard, lustrous scales, like the present garpike; the Placoderms, by large plates, like turtles, and often, like them, move by paddles (Pterichthys.)

IV.—Carboniferous Age.

This age is entirely unlike the previous. It is especially remarkable for its vast deposits of coal. It is divided into three periods:

The Subcarboniferous Period.

The Carboniferous Period.

The Permian Period.

The first period gave birth to vast marine deposits, with rich fields of Crinoids; the third is a period of transition to the Mesozoic Age; the Carboniferous Period proper is for us the most interesting to study.

The chief characteristic of the Carboniferous is that here is found, for the first time, a grand terrestrial flora, covering immense surfaces—whole continents. The time has come when the lands forming in the shallow seas gradually reach the surface, and break the unlimited extent of the ocean of former ages. The newly-emerged continents cover themselves with extensive swamps and stately forests with luxuriant foliage. The monuments of this grand forest epoch are found in the coal-measures of North America, England, and all the continents. This age was a paradise of terrestrial vegetation.

How Do These Masses of Coal Occur?

We find that these masses occur, not in veins, like gold, silver, &c., but in regular horizontal sheets parallel with the strata; these seams usually rest upon sandstone or conglomerate, hardly ever upon limestone.

Just above the sandstone we find a layer of fire-clay; above this the coal; above the coal we often find shales containing numerous impressions of fossil plants and trunks of trees.

These seams or beds of coal are found in great numbers; in the Appalachian Mountains there are some forty of them; in Nova Scotia sixty, and in England nearly a hundred.

(Number and extent of coal fields in N. America—See Dana.)

Kind of Plants. Four species of tree peculiar to this age.

(*a.*) The *Lepidodendrons*, of which there are about forty known species. These trees attained a height of sixty to eighty feet. Their leaves were sometimes twenty inches long, and their trunks a yard in diameter. The scars of their leaves are arranged very regularly in quinquex-like scales; hence the name of the tree.

(*b.*) The *Sigillarias* were great clumsy trees, consisting of a simple trunk, surmounted with a bunch or panicle of slender, drooping leaves, with a bark often channelled, and displaying impressions or scars of the old leaves, which, from their resemblance to a seal, *sigillum*, gave origin to their name.

(*c.*) The *Stigmariæ.* All that is known of these is that they were provided with long roots, which carried the reproductive organs, and in some cases were as much as sixty feet long.

(*d.*) The *Calamites*, or mare's-tail family, as they are sometimes called. These seem to have grown somewhat after the manner of our asparagus, by means of an underground stem, while new buds issued from the ground at intervals. In addition to these four species we find *tree-ferns* and herbaceous ferns, which composed seven-eighths of the vegetation of this period.

These ferns differ chiefly in some of the details of the leaf. There were also a few representatives of Pines, prophetic of the next age. The great majority of these plants are Cryptogams of the group of Acrogens. The aborescent vegetation is composed of comprehensive types, looking up to the Gymnosperms. The great mass of the vegetation, however, is made up of ferns, whose organic characteristic is the full development of the leaf. The Carboniferous Age is the great age of verdure—magnificent, luxuriant, but deprived of floral beauty.

This character, however, prepared it for its great function in nature: purifying the atmosphere from the excess of carbonic acid gas, and making it fit for air-breathing animals, and storing coal in the bosom of the earth for the future use of man.

If, during this period, the vegetable kingdom had nearly reached a maximum as to quantity, the animal kingdom, on the contrary, was very poorly represented. The animals which did exist were very analogous to those of the previous ages. But amphibious reptiles, mostly Labyrinthodonts, which unite some characters of the true reptiles, are added to the fauna.

Formation of These Deposits.

In order to explain the presence of coal in the depths of the earth, a large number of hypotheses have been advanced, only two of which are possible.

A.—Can the coal-beds result from the transport by water, and burial under ground, of immense rafts formed of the trunks of trees? This hypothesis has against it the vast extent and regularity of these sheets of coal, and the enormous height which must be conceded to the raft in order to form coal seams as thick as those which are actually found in our collieries; for it has been proved that coal deposits can only be about seven-hundredths of the volume

of the original material. It would require immense rivers to float such rafts, but as there were no large continents and mountains at this time, there could have been no large rivers. We are, therefore, driven to the conclusion that this hypothesis is inadmissible.

B.—By far the most probable explanation is that offered by Prof. Lesquereux, of Ohio, called the "peat bog" theory—*i. e.*, that coal results from the fossilization of plants, which has taken place in the very place where the plants lived and died. When sandbars are formed along the coast, shutting up a large lagoon, as Pamlico sound, for instance, this lagoon, from being filled by deposits brought down by rivers, soon becomes shallow, and as the water, as before explained, becomes fresh, vegetable growth is made possible. First, infusorial vegetation will be deposited, making a soil for other plants. This becomes the fire clay. Swamp plants soon fill the lagoons; trees grow on the top. These decay in water, and form the material of the coal. By a process of subsidence these swamps are covered by the water of the sea, and the vegetation thereby killed. While the water is still shallow, shales with the plants buried in them are formed by the action of the sea, but, as the process of subsidence continues, the formation of sandstone and limestone results.

As the land rises again, this new sandstone becomes the foundation for a new bed of coal. These plants, thus buried under water, develop an acid which prevents their being fully burnt, and allows the formation of coal. The shales, which are found above the coal, often contain the imprints of plants and the remains of fishes. A good example of this process going on at the present day is to be seen in the *Dismal Swamp* of Virginia.

This theory, therefore, is the most probable, and the one generally accepted by geologists. It, of course, forces us to admit a series of oscillations of the continental areas as numerous as the number of the coal seams themselves.

We thus bring to a close the history of the Palæozoic times, or of the three great beginnings.

During these long ages the growth of the continent of North

America continued from north to south. Before life existed, the Laurentian Mountains, including the Adirondacks, were already dry land. The Green Mountains were raised during and at the end of the Silurian. The main Appalachians were upheaved after the Carboniferous, and that great revolution raised forever above the waters of the ocean the eastern half of North America, and closed the Palæozoic times.

Again, we may divide the geological period into three great ages—

1st. The Silurian, Devonian, and Carboniferous—the "Water Age, or Oceanic Era," since the ocean was predominant.

2d. The Reptilian Age—the Triassic, Jurassic, and Cretaceous. The Mediterranean, or Middle Age.

3d. The Mammalian Age. This may be called the "Continental Age," as the land was upraised.

We have already treated of the first; we now come to

V.—The Mesozoic, or Reptilian Age.

This whole age is characterized by large, powerful reptiles. A few small ones appeared in the Carboniferous Age, but were merely prophetic types. Reptiles now culminate in animals of immense size.

Two kinds of Reptiles.

I. Amphibian.
II. True Reptiles.

The Amphibians, when young, or in the tadpole state, breathe, like fish, by means of gills, but afterwards breathe by lungs. Such are frogs, salamanders, and toads.

True reptiles always breathe with lungs, having no gills at any period of life. As, for example, the turtle, whose eggs are very much like those of a bird. Thus the difference between the amphibian and true reptiles is in their embryonic state. The amphibian, during its growing stage, lives in water—the life of the fish; it then undergoes a metamorphosis, which makes it a land as well as a water animal. True reptiles undergo no such transformation. True reptiles are very much like birds in structure. In the Reptilian Age we have three series of rocks, called—

1st. The Triassic Period—because separated into three kinds of rock, viz.: (*a.*) Red sandstone, mottled with green. (*b.*) Shell limestone. (*c.*) Red marl.

2d. The Jurassic period—because the Jura Mountains are formed of this kind of limestone. It is characterized by a succession of limestones which show a great amount of marine life.

3d. The Cretaceous period. This is also characterized by a predominance of limestone full of life.

Now, how do reptiles develop or appear? Their progress is according to their grade of organization. In the Carboniferous rocks small amphibian reptiles have been found, and tracks of large ones; this being often the only means we have of knowing that they existed in those ages.

In the Triassic we find gigantic amphibians, *e. g.*, monstrous, salamander-like animals, which, judging from the size of their jaws and skulls which have been found, must have been nine feet long. The Mastodonsaurus—or the Salamandroid labyrinthodon—so called on account of the numerous windings seen in a section of the tooth. These are very large, much larger than any previous reptile. The skeletons of many species have been found, but a much larger number are known only by their *footprints.* In the Connecticut valley, and to some extent also in New Jersey and Pennsylvania, the surface of the sandstone is marked with tracks of reptiles, many of which are now preserved in Amherst College and Princeton Museum. One hundred and twenty species of animals have been indicated merely from these tracks. Here, at the end of this period, touching the Jurassic, we find, perhaps, the first creation of birds. In these red sandstones we find not bones but tracks, which Hitchcock believes to belong to birds, though the fact is still doubtful. Some place these rocks at the bottom of the Jurassic Period, but Prof. Hitchcock, who has made them a subject of special study, places them at the top of the Triassic. This is most probably their true position—*i. e.*, between the Triassic and Jurassic. In this period there are a few Saurians, but the Amphibans still predominate.

In the Jurassic Period appear immense marine animals. Here we have the beginning of true Saurian Reptiles, at the bottom of

the Jurassic, in two or three distinctive forms. The first belong in the water, and have paddles instead of feet. This family is called Enaliosaurians. Here the *Ichthyosaurus* (*ιχθύςσαύρος*—fish lizard,) and *Plesiosaurus* make their appearance. These are the two great forms characteristic of the age, both living in and paddling through the water. They are immense animals, often being from twenty-five to thirty feet long, especially the former. In the museum of Princeton College we have the head of one of these, about four feet long, and also a fin or paddle of the same, and several entire skeletons. The *Ichthyosaurus* has four paddles—is very bulky, having a strong head and body and a long tail; lives exclusively in the water, and is carnivorous, the latter being one of its leading characteristics. *The Plesiosaurus* is characterized by a very long neck, short head and tail. The long neck enabled them to catch animals both in and out of the water. This reptile is scarcely as large as the former. The largest known specimen of the Plesiosaurus, found in the lias of Yorkshire, is now in the museum of the Royal Society of Dublin, being twenty-two feet four inches in length, of which we have a cast in Princeton Museum. Another class of reptiles belonging to this period is the Pterodoctylus (*πτερόν*, a wing; and *δάκτυλος*, a finger.) It was at first disputed whether these were birds, bats, or flying reptiles. Cuvier was the first to detect the truth, and to prove, from its organization, that it was a Saurian. Accordingly, they were flying reptiles, or Pterosaurs. One has been found which measured twenty-four feet from tip to tip of its wings. There were also in this period *land reptiles,* but much smaller, as crocodiles, &c. There were no turtles, to any extent. In the Jurassic Period we have, therefore, (1.) Water reptiles — predominant. (2.) Land reptiles—not very abundant. (3.) Flying reptiles. We next come to the

Cretaceous Period.—This is still very much the same. The Ichthyosaurs, though, are not so large or numerous as in the preceding. We find, however, nearly all the same animals. The name Cretaceous was given to this epoch in the history of our globe, because the rocks deposited by the sea at its close, are

almost entirely composed of *chalk* (carbonate of lime.) But, in addition, we find large land reptiles—the Dinosaurs, (δεινος, terrible,) with some of the characters of birds and mammals; the Megalosaurus, which lives *entirely* on the land; the Hadrosaurus of New Jersey; the Iguanodon. It is suprising what immense development and extraordinary dimensions the Saurian family attained at this epoch. These animals, which, in our day, rarely exceed a few yards in length, attained, in the Dinosaurs of the Cretaceous period, as much as twenty to twenty-five. The marine lizard, which we notice under the name *Mosasaurus*, was then the scourge of the seas, playing the part of the Ichthyosaurus of the Jurassic Period. So the stages of the progress of life during the Mesozoic are marked by the successive predominance of—

1st. The large Amphibian Reptiles.

2d. The Aquatic Reptiles—with Reptilian Birds.

3d. The Gigantic Land Reptiles.

Plants of the first two periods. Though, at first, Calamites and Horsetails, almost arborescent, (Equisetites,) are still present, Pines, Cycads, and other coniferous trees begin to be abundant, and soon become characteristic of the age. The foliage and vegetation is slender and poorly developed.

In the Cretaceous Period, however, important changes take place, which prepare for the opening of a new age. The vegetation assumes a new aspect, by the first appearance of Monocotyledons and Dicotyledons. Among animals, the fishes of ancient times—the Ganoids—give place to the modern forms of our common osseous fishes—the salmon, the perch, and the like.

In the preceding periods all rocks are of marine origin. In the Cretaceous, fresh-water deposits begin to be found, indicating the increase of land, which is also marked by the successive upheaval of mountain chains. During the Mesozoic Age, in Europe, the Jura and most of the mountains of Central Germany were raised, and the upheaval of the Pyrenees closed the age by a revolution which had the greatest influence in shaping the continent and changing the character of all its organized nature. In America, the Rocky Mountains began to rise, preparing a new continental age.

VI.—The Tertiary or Age of Mammals.

The upheaval of large chains of mountains, the Pyrenees in Europe, a part of the Rocky Mountains in America, accompanied by a general rise of the continents everywhere, prepared the foundation for a new age of life.

The rock formations are no more co-extensive in all continents; they become more local. Nor are they any more exclusively marine. Large estuaries, extensive basins in the interior of the continents, separated from the sea, receive fresh-water deposits, which make almost one-half of the Tertiary formations. Frequent alternations of the two kinds, as in the classical Tertiary basin of Paris, indicate a series of oscillations, of rises and subsidences above and below the sea, such as we have seen in older periods. The continents have not yet come to a stand-still. It is only after the closing of the age by the great revolutions which gave birth to the Alps, the master mountain system of Europe, and raised to their present height the vast systems of the western highlands of North America, from the Rocky Mountains to the Sierra Nevada, that these continents assumed about the shape they now have. The great western plains, which, during the Cretaceous Period, were still the bottom of a part of the ocean separating the Atlantic from the Western Highlands, were raised above the water, and for the first time in the geological history of America the two large, but isolated, islands were consolidated into one continent.

Compared with the preceding ones, the Tertiary Age is eminently a *Continental Age.* The larger land area, the greater diversity of geographical forms of its surface, both of contours and altitude, the consequent diversity of climates, fitted it admirably for the inhabitation of large land animals, and for a richer development of the life-system in every direction. While the numerous Mediterranean seas of the Mesozoic Age, and their borders, favored an exuberant Reptilian life, the new conditions of the Tertiary Age were prepared for the development of a rich Mammalian life.

The Tertiary Age has been subdivided into three periods: a

Lower, Middle and Upper Tertiary, for which Lyell substituted the names of Eocene, Miocene and Pliocene. The etymology of these names is derived—Eocene, from the Greek ἠώς, *dawn*, and καίνος, *recent;* Miocene, from μείων, *less*, καίνος, *recent;* and Pliocene, from πλείων, *more*, καίνος, *recent;* by which is meant to express that at these periods the proportion of species identical with the ones now living is greater or less. These proportions are, for England, about one to five per cent. in the Eocene; fifteen to forty per cent. in the Miocene; fifty to ninety per cent. in the Pliocene.

The Life System in the Tertiary Age.

Plants. A great prevalence of Dicotyledons over all the other classes of plants is the great feature of the Tertiary vegetation. The forest trees, oaks, maples, sassafras, magnolias, &c., are more and more similar to those of the present day as the age advances. The landscape is very little different; only palm trees in considerable number, indicate in our latitudes, a warmer climate, which gives it, especially during the Miocene, a semi-tropical aspect.

The *Invertebrates* bear a general resemblance to the modern types, even when many of their genera are extinct, and quite a number of species are still living.

Among the *Fishes*, the great prevalence of osseous fishes, such as salmon, perch, herring, &c., and an abundance of sharks of large size and varied species, represent the class of the selachians.

The large *Reptiles* of the Meszoic have all disappeared. Not one of the monstrous Dinosaurs, so characteristic of the Cretaceous, is to be found. Crocodiles, turtles and the first serpents are the main representatives.

Few *Birds* are found, and are similar to those living in man's age.

But the great character of the Age is the abundance of *large Mammals*, of all orders, which suddenly make their appearance in the Eocene, and grow more diversified and powerful in the succeeding periods. Though heralded in the Mesozoic by a few small ones, nearly all of the marsupial type, with bird-like char-

acters, which are even absent from the Cretaceous, this large creation appears at once in force in the Eocene.

Cuvier first described these new types of the Eocene of Paris, and since vast numbers have been found in all continents in similar conditions.

The Eocene mammals are mostly of "comprehensive" types, uniting characters afterwards distributed among various orders—such as Palæotherium, with characters of ruminants and pachyderms; Anoplotherium, &c. In America, in the Eocene of Wyoming, the Palæosyops, the family of the Dinocerata, (see our museum,) have the same character.

In the *Miocene*, the large herbivorous mammals and pachyderms predominate; elephants, mastodons, dinotheriums, stags, horses, &c., though carnivorous, bears, &c., and even monkeys, are not wanting.

In the *Pliocene*, the carnivorous become relatively more numerous, though all the other groups are present; nearly all the typical forms of mammals of our day are abundantly represented, but all the species without exception are now extinct.

The Mammalian Age was truly the time of the fullest development of this highest type of animal life below man. With man, another age begins—the age of the mind and of the spirit.

A glance on the development of life, as just contemplated in geological history, demonstrates the complete accordance of the successive appearances of animal and plant forms with the rank they occupy in the scale of perfection, and manifests the unity of a plan which presided in all the creation from the very beginning to its final completion.

The Tertiary age is closed by the last great revolutions which have modified the surface of the globe and given to its continents their present shape and extent. The gradual growth of the great land-ma~~rks~~ was completed, and their final forms determined, by the upheaval of their highest mountain systems, which then attained their present elevations. The Rocky Mountains and Sierra Nevada, in North America; the Andes, in South America; the Himalayas, in Asia; the Alps, in Europe, all date their final structure from the close of the Tertiary, and carry on their

tops fragments of tertiary strata as witnesses of the time of their upheaval.

A *Quaternary* or *Post-tertiary* period, marked by tremendous floods of atmospheric waters, which, falling in snow in the polar and temperate latitudes, soon covered all these regions with a vast sheet of ice of thousands of feet in thickness, causing what is now termed the great Ice Age, already belongs to the Age of Man. By grinding the hard, rocky surfaces, disintegrating and transporting their materials by the double action of abundant rains, frost and ice, scooping out valleys, spreading alluvial deposits almost everywhere, these various agencies prepared the soil for agriculture and the work of man.

It was probably in some interval of rest and quiet during the middle of this period that the first man was placed on earth, where everything had been prepared for his advent and the use of the Human Race.

FINIS.